
Occurrence and group characteristics of minke whales, *Balaenoptera acutorostrata*, in Massachusetts Bay and Cape Cod Bay

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The minke whale, *Balaenoptera acutorostrata*, is one of the smallest of the baleen whales. Despite exploitation by the whaling industry in recent years, comparatively little is known about the biology and behavior of this species. The minke has a cosmopolitan distribution, although recent biochemical studies suggesting large genetic differences between oceanic populations (Amos and Dover, 1991; Hoelzel and Dover, 1991; van Pijlen et al., 1991; Wada and Numachi, 1991; Wada et al., 1991) have cast some doubt on the long-held belief that all populations constitute a single species. As is the case for most baleen whales, minke whales appear to migrate to high latitudes in the summer for feeding and to travel to tropical waters in the winter for birthing (Horwood, 1989; Mitchell, 1991). However, specific breeding grounds have yet to be unequivocally identified, and it is unknown whether both sexes and all age classes in a population undertake the migration to low latitudes. In some temperate, subtropical, and tropical areas, minke whales are observed throughout the year (Ivashin and Votrogov, 1981; Best, 1982; Gong, 1987; Stern, 1990), although it is unclear whether these sightings represent year-round residency on the part of particular individuals or a more

general movement through the area by members of one or more populations.

In recent years, much has been learned about other mysticetes through long-term studies based on the identification of individual whales (see Hammond et al., 1990). Unfortunately, minke whales lack the great variability in natural markings that have facilitated detailed investigations of larger confamilials (such as humpback whales, *Megaptera novaeangliae*). This, together with the difficulty of photographing them owing to their small size and great speed, has hindered studies based on photographic identification, although studies of small localized populations have been possible (Dorsey, 1983; Dorsey et al., 1990; Stern et al., 1990). In general, however, studies of free-ranging minke whales have been few, and their population structure, social organization, and migratory movements remain poorly understood.

Minke whales are commonly observed in the waters of Massachusetts Bay and Cape Cod Bay in New England, and since 1979, sightings of this species have been routinely recorded from both commercial whalewatching vessels and dedicated surveys. In this paper, sighting records are examined in an effort to describe the temporal distri-

bution, seasonal abundance, and feeding behavior of minke whales in this region. These data are then compared with information reported for this species from other areas, notably within the North Atlantic.

Methods

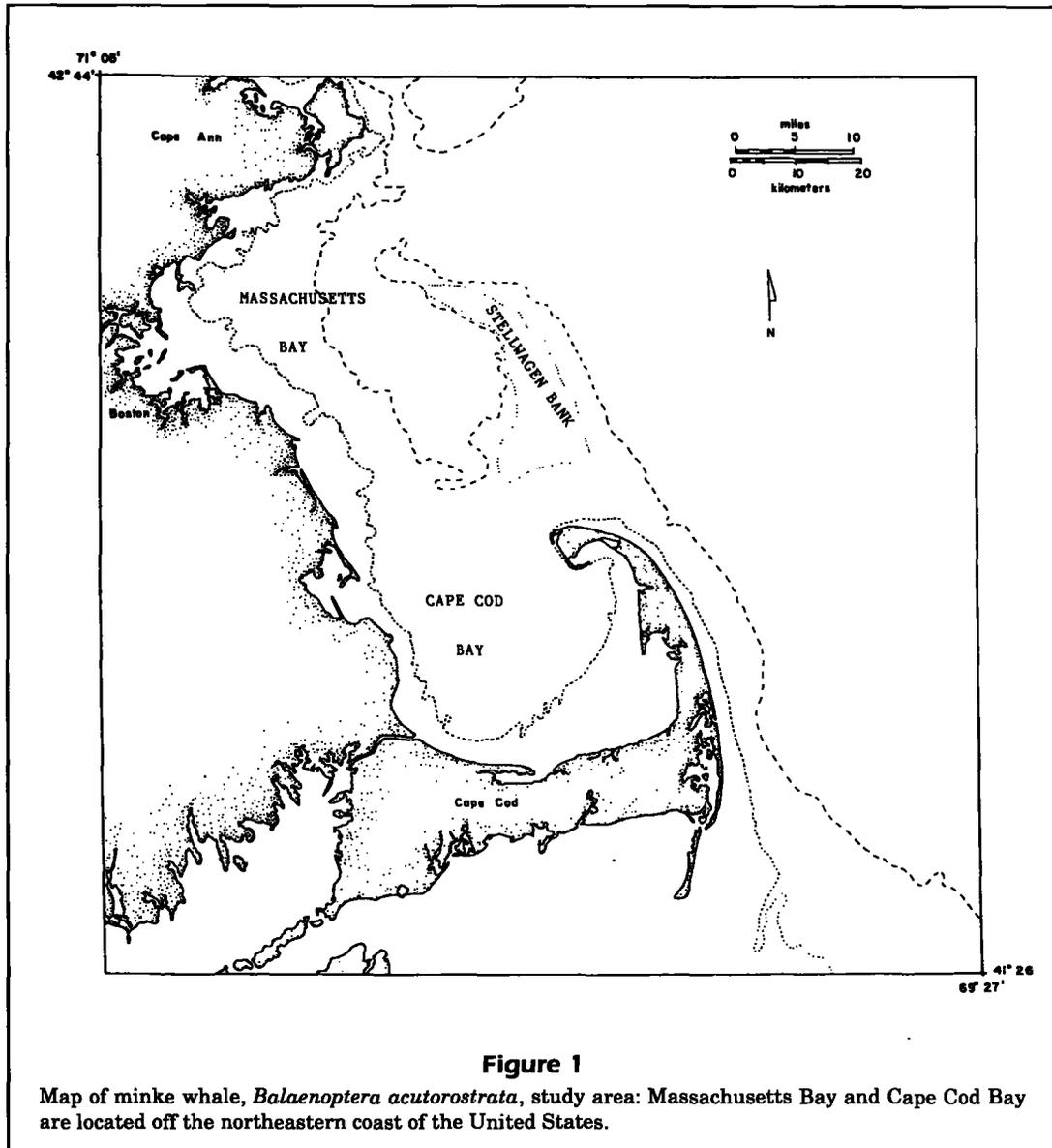
Study area

The study area includes the coastal region dominated by Cape Cod Bay and Massachusetts Bay along the northeastern coast of the United States (Fig. 1). Cape Cod Bay is a semi-enclosed sandy basin with a maximum depth of 60 m. Massachusetts Bay lies north of Cape Cod; depths range from 40 m to 100 m except on Stellwagen Bank, an elongated glacial feature of sand and gravel approximately 25 km in length, which has a minimum depth of 18 m.

Effort

Data were collected between 1979 and 1992. The total number of cruises conducted during this period was 10,249 (this figure excludes those made in certain weather conditions, as noted below); of these, 9,728 (94.9%) were made from 30-m commercial whalewatching vessels operating between April and October of each year from Provincetown, Massachusetts. Additional cruises ($n=374$) were made from a 12-m diesel-powered research vessel beginning in the autumn of 1983, and 77 cruises were made from a 14-m auxiliary ketch beginning in the autumn of 1985. The remaining non-whalewatch cruises were made primarily from a 5-m inflatable boat. Because virtually all of the whalewatching trips were approximately four hours in length,

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all cruises of eight hours or more were broken into separate four-hour blocks in an attempt to standardize temporal effort.

Cruises aboard the 12-m research vessel ran four fixed tracks in Cape Cod Bay between January and May each year. The tracks ranged from six to nine nautical miles in length and were approximately four nautical miles apart. These cruises searched specifically for North Atlantic right whales, *Eubalaena glacialis*; however, all marine mammal sightings were recorded. Owing to frequent unfavorable weather, the tracks were not surveyed equally; effort was concentrated mainly in the more sheltered eastern portion of the Bay. Cruises aboard the 14-m ketch occurred throughout the year and ran either

four fixed tracks on Stellwagen Bank or directed searches in areas where large concentrations of whales had been recently reported or were known to have occurred in the past. The fixed tracks covered the southern portion of Stellwagen Bank, although two of the tracks extended northward to include the northwest corner of the Bank. The tracks on the southern portion of the Bank ranged from six to nine nautical miles in length, all tracks being approximately three nautical miles apart from one another. Again, all cetacean sightings were noted, although the majority of these cruises were directed primarily toward humpback whales. The remaining non-whalewatch cruises were nonrandom, searching areas where large numbers of whales had been recently

reported. All whalewatching cruises were nonrandom and search tracks for these cruises were generally decided by the captain of the vessel.

Search effort was based on four-hour trips. It was not possible to quantify precisely observer effort; time spent searching inevitably varied somewhat between trips. However, because at least one observer was searching for whales constantly for the duration of each cruise (both on the whalewatching cruises and dedicated surveys), it is unlikely that significant differences existed in effort between months or years. Furthermore, because all trips were primarily focused on larger mysticetes, virtually all sightings of minke whales were opportunistic; consequently, search effort towards this species was effectively even throughout the study period. To minimize the possibility that minke whales were present but not sighted owing to bad weather conditions, all cruises conducted in fog or in sea states above Beaufort 4 were excluded from analysis. The total number of cruises for each month of all years is summarized in Table 1.

The following information was routinely collected: date, time, location (by using LORAN-C) and, where determinable, group size and behavior. Although photographs were occasionally taken during this study, the resulting data are not discussed here.

The following terms are used in this paper: **singleton** refers to a lone animal, **group** refers to two or more animals that were considered associated if they were swimming side by side and were generally coordinating their speed and direction of movement during their surfacing and diving behavior. Animals that were farther apart and did not show such coordination of movement were not considered associated. It is possible that two or more minke whales that were not side by side were in acoustic contact and therefore associating; however, such associations are impossible to identify in the field and were not considered in this study. **Feeding** refers to a whale observed with its mouth open or lunging at the surface where prey was visible in the water. It is highly likely that there were other instances in this study when

feeding occurred below the surface but could not be observed; consequently, the feeding rates reported here should be considered minimum values. **Calf** refers to an animal considered to be a first-year calf if it was observed in close association with a large whale and was not more than half the apparent length of the latter (presumed to be the mother).

Results

Temporal distribution

There was a significant difference in the sighting rate of minke whales (number of whales observed per trip) from year to year ($\chi^2_{13} = 2188.7, P < 0.001$); the maximum sighting rate was recorded in 1989 and the minimum in 1982 and 1986 (Fig. 2). Minke whales were observed in all months except January and February and showed significant differences in abundance by month (pooled over years) (Fig. 3). Pairwise comparisons of mean monthly values for the period of greatest effort (March through October) were conducted by using a one-way analysis of variance and are revealed in Table 2. There were no significant differences in the number of sightings between the months of March, April, May, and June (hereafter collectively termed "spring"), nor between July, August, September, and October (hereafter referred to as "summer-autumn") (Table 2). However, three of the four months of spring differed significantly from those of summer-autumn in all pairwise comparisons. The exception was March, for which sighting rates were not significantly different from those of any other month.

Calves

Only three calves were observed during the entire study period. Each sighting occurred at a different time of year: 8 May 1981, 3 October 1989, and 28 August 1991. Two of the calves were part of a pair, and the third was part of a group of three.

Table 1

The number of cruises conducted each year and each month for all years combined (1979-92) for minke whales, *Balaenoptera acutorostrata*, in Massachusetts Bay and Cape Cod Bay. Cruises in fog or where the sea state exceeded Beaufort 4 were excluded.

Year														Month (all years combined)													
1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
No. of cruises	127	207	414	517	630	723	789	878	875	972	989	979	1110	1039	No. of cruises	26	57	114	532	1409	1625	2091	2118	1415	793	44	25

Group-size frequency

A total of 5,806 minke whale sightings were recorded for which the group size could be reliably determined. Observed group-size frequency ($\bar{x}=1.06$, $SD=0.315$) for singletons ($n=5,536$) was 95.3%, for pairs ($n=223$) 3.8%, and for trios ($n=46$) 0.8%. With the exception of a single group of five whales, no groups larger than three were observed during this study.

Feeding behavior

A total of only 27 (0.4%) of 6,266 sightings involved confirmed feeding at the surface. These sightings occurred in all months between May and October inclusively. In 24 of the 27 sightings of feeding, group size was recorded: single animals accounted for 21 (87.5%) of these, two sightings involved pairs, and one sighting a group of three whales.

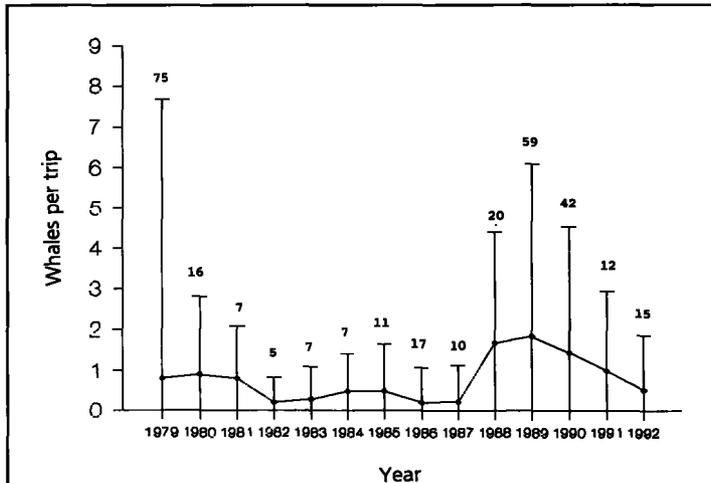


Figure 2

Observed variations in occurrence (mean and standard deviation) of minke whales, *Balaenoptera acutorostrata*, by year (1979-92) in Massachusetts Bay and Cape Cod Bay. Numbers above the bars represent maximum value for any one trip in that year.

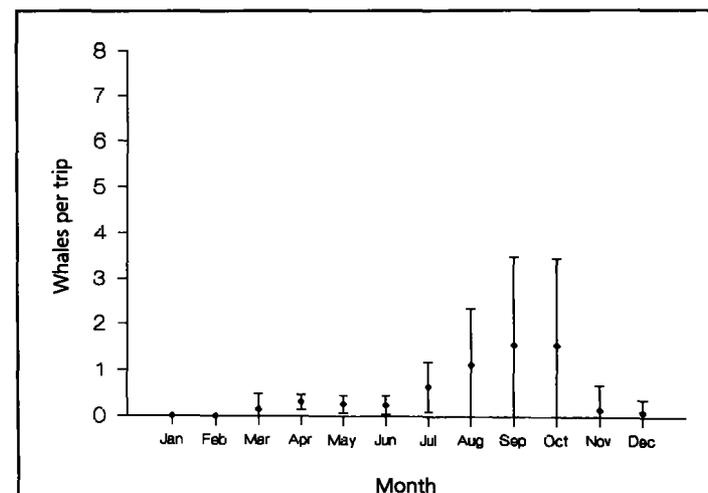


Figure 3

Observed variations in occurrence (mean and standard error) of minke whales, *Balaenoptera acutorostrata*, in Massachusetts Bay and Cape Cod Bay by month for all years (1979-92) of the study.

Discussion

Temporal occurrence

Minke whales appear to arrive in the waters of Cape Cod Bay and Massachusetts Bay in the early spring and in some years occurred as late as December. The considerable interannual variability in the abundance of minke whales probably reflects variation in effort (see Table 1) or fluctuations, or both, in the abundance and distribution of prey. That it may be linked to the latter is suggested by the very low sighting rates recorded in 1986 and 1987, two years in which the local abundance of sand lance (*Ammodytes* spp.) is known to have been at a minimum and when other piscivorous mysticetes were largely absent from the study area (Payne et al., 1990). However, the concentration of effort on other mysticetes (and consequently on areas preferred by them) may have introduced a bias against minke whale sightings if these whales exhibit significant differences in habitat preference (this is currently unknown). Interannual variability in abundance has also been reported in other areas and has been similarly linked to prey availability, as well as to effort and, in Arctic areas, distribution of sea ice (Sigurjónsson, 1982; Larsen and Øien, 1988).

There was also considerable variation in abundance from month to month. The data reported here indicate a distinct peak in abundance beginning in July and continuing through September. No minke whales were observed in January or February: although this may have been due to the markedly decreased sampling effort during these two months, this appears unlikely given the dedicated (i.e. non-whale-watching) nature of the surveys conducted at this time and the frequently calm conditions which were a prerequisite for such cruises.

This general pattern of occurrence (abundant in summer, scarce or absent in winter) is similar to that reported for other high-latitude

Table 2

Results (from a one-way analysis of variance) of pairwise comparison of monthly mean sighting rates for minke whales, *Balaenoptera acutorostrata*, in Massachusetts Bay and Cape Cod Bay (1979–92). Figures shown are *P* values; significant differences are shown in bold type.

Month	Apr	May	Jun	Jul	Aug	Sep	Oct
Mar	0.69	0.88	0.98	0.06	0.05	0.06	0.08
Apr		0.64	0.44	0.01	0.01	0.01	0.02
May			0.76	0.01	0.01	0.01	0.02
Jun				0.01	0.01	0.01	0.02
Jul					0.19	0.10	0.13
Aug						0.47	0.58
Sep							0.87

minke whale populations, including those elsewhere in the North Atlantic. Data from Newfoundland, Iceland, and West Greenland show a similar seasonal distribution in which minke whales arrive in spring, are most abundant during mid- to late summer and begin to leave in the autumn (Sergeant, 1963; Mitchell and Kozicki, 1975; Kapel, 1980; Sigurjónsson, 1982). However, a few minke whales have been reported off western Newfoundland and Iceland in both November and December (Sergeant, 1963; Sigurjónsson, 1982), and minke whales have occasionally been caught off West Greenland between November and February (Kapel, 1980). The same seasonal occurrence is seen in the waters off Norway and in the Arctic where a few whales have been observed through the winter (Jonsgård, 1951). High-latitude areas of the North Pacific and the Antarctic are also characterized by a seasonal distribution similar to that observed in the North Atlantic (Shimadzu, 1980; Dorsey, 1983; Gong, 1987; Stern, 1990). Since most of these studies were not based on identified individuals, it is not clear whether minke whales in these areas are resident for long periods or whether the reported sightings represent short-term occupancy or transient passage by numerous animals.

If the apparent decrease in abundance of minke whales in Massachusetts Bay in autumn and winter is, as suggested above, unrelated to effort, it may reflect a migration of most minke whales to lower latitudes at that time of year. Data on the winter distribution of minke whales are scarce. In the southwestern North Atlantic, minke whales have been reported in the waters between Bermuda and the Antilles between the months of January and March (Mitchell, 1991; Mattila and Clapham, 1989; Mattila et al., in press). Stranding data show evidence of the presence of minke whales in the waters off Florida from December to February.¹ Winter sightings, while

infrequent, have also been reported in the western Gulf of Maine and in waters southeast of Cape Cod (CeTAP²).

In the Southern Hemisphere, minke whales are also reported in lower latitudes during the winter. Off Brazil, as well as in the waters of the southwestern Indian Ocean, minke whales are mainly present in winter and spring (Williamson, 1975; Best, 1982). However, some have been reported trapped in sea ice in the Antarctic between May and October (Taylor, 1957); this finding, together with year-round sightings of minke whales in areas such as California (Stern, 1990), Greenland, Norway, and the Arctic suggests that a few animals may overwinter at higher latitudes.

Calves

During the fourteen years of this study only three minke whale calves were observed. Sightings of minke whale calves in high-latitude areas of the North Atlantic are rare; this is not the case for certain other mysticetes (e.g. humpback whales [Clapham and Mayo, 1987]; fin whales, *Balaenoptera physalus* [Clapham and Seipt, 1991]; North Atlantic right whales [Hamilton and Mayo, 1990]). Only two minke whale calf sightings were reported in the 1982 Cetacean and Turtle Assessment Program (CeTAP) study, both occurring just south of Cape Cod (one in

¹ Mead, J. Curator of marine mammals at the Smithsonian Institution. Natl. Mus. Nat. History, Smithsonian Institution, Washington, D.C. 20560. Unpubl. data, 1992.

² CeTAP (Cetacean and Turtle Assessment Program). 1982. Characterization of marine mammals and turtles in the mid- and North Atlantic areas of the U.S. Outer Continental Shelf. Final Rep. of the Cetacean and Turtle Assessment Program, Univ. Rhode Island, to the Bureau of Land Management, Washington, D.C.

April and the other in June). In the waters off Quebec, one pair (adult and calf) was observed in late July (Perkins and Whitehead, 1977). Similarly, calves have not been reported in the waters off the west coast of the United States (Dorsey, 1983) and are also not commonly observed on the high-latitude feeding grounds in the Southern Hemisphere (Kasamatsu et al., 1988).

In the North Atlantic, the majority of minke whale calf sightings have occurred in lower latitudes. In the southwestern North Atlantic, calves have been sighted in the waters between Bermuda and the Antilles (Mitchell, 1991) as well as in the northern Leeward Islands (Mattila and Clapham, 1989).

One possible explanation for the absence of calves in higher latitudes is that minke whales wean their calves before entering these waters. According to Jonsgård (1951), North Atlantic minkes are thought to calve between November and March, and nursing is believed to last for only four to five months. This information would concur with reports of no or few lactating females found during the summer off both Norway (Jonsgård, 1951) and Newfoundland (Sergeant, 1963; Mitchell and Kozicki, 1975).

In the Southern Hemisphere, it also appears that females wean their calves before reaching higher latitudes (Best, 1982; Kato and Miyashita, 1991). However, there is evidence (at least in the Southern Hemisphere) that pairs (mother and calf) may remain in low or middle latitudes until weaning occurs (Kato and Miyashita, 1991), which suggests that some minke whale populations segregate by reproductive class.

Segregation by both sex and age class has been described in many minke whale populations. Whaling data from the North Atlantic, the North Pacific, and the Southern Hemisphere suggest that minke whales segregate by sex during their summer migration (Jonsgård, 1980; Kasamatsu and Ohsumi, 1981; Sigurjónsson, 1982; Larsen and Øien, 1988; Wada, 1989) as well as on their feeding grounds (Jonsgård, 1980; Ohsumi, 1983; Larsen and Øien, 1988; Wada, 1989; Kato et al., 1990a). Segregation by maturational class has also been recorded in minke whales (Best, 1982; Ohsumi, 1983; Wada, 1989; Kato et al., 1990a). Jonsgård (1951) suggested that newly weaned calves and juveniles off Norway probably do not migrate north together with larger animals, which is in agreement with data reported by Wada (1989) for areas off the Pacific coast of Japan.

Neither the sex nor age class of the minke whales in the waters of Cape Cod and Massachusetts Bay areas is known because it is not currently possible to determine either in the field. Stranding data from this area give a mean length for minke whales of 505 cm ($n=35$, $SD=140.3$ cm); comparison of this fig-

ure with data on lengths of individuals caught in North Atlantic whaling operations (Jonsgård, 1951; Sergeant, 1963; Mitchell and Kozicki, 1975; Christensen, 1981) would suggest that the majority of animals that have stranded here were immature. The sex ratio of stranded animals was approximately even. Whether this sample is representative of the general population or only of those more likely to strand is unknown.

Group size

In this study approximately 95% of all minke whale sightings were singletons. Single animals appear to predominate in other studied areas, although there is evidence of group size changing by season, latitude, sex and age class, and when prey is present. In some cases, however, it is unclear whether animals reported in large groups (particularly when feeding) are actually associated with or are simply attracted to a common location by the presence of prey.

Data from the Mingan Islands in the Gulf of Saint Lawrence show that minke whales are usually solitary, although they are seen in large coordinated groups of five to fifteen animals when actively feeding.³ Aerial surveys conducted off Iceland in June and July reported a mean school size of 1.1 (Gunnlaugsson et al., 1988). Jonsgård (1951) found that minke whales tend to travel alone off the western coast of Norway, noting only a few sightings consisting of pairs; in the Arctic, single animals were predominant in catches, although groups of three to ten animals were more common than pairs. In the western North Pacific off the Chukotka coast, sightings were usually of single animals. However, when polar cod arrive in late June and in July, minke whales are often observed in groups of five or six animals (Ivashin and Votrogov, 1981); again, it is not clear whether such groups are truly associated according to the definition of 'group' used here. Information on minke whales in the Southern Hemisphere also indicates variability in group size with changes in latitude and season as well as with differences in maturational class (Williamson, 1975; Best, 1982; Kato et al., 1989; Kato et al., 1990b).

The group size frequency of minke whales observed in the Massachusetts Bay and Cape Cod Bay areas did not appear to change with time of year or with the presence of prey (on the basis of sightings where confirmed feeding occurred). Because the majority

³ Sears, R., F. W. Wenzel, and J. M. Williamson. 1981. Behavior and distribution observations of Cetacea along the Quebec north shore (Mingan Islands), summer-fall 1981. Mingan Islands Cetacean Study, Montreal, Unpubl. Rep., 72 p.

of sightings were singletons it is possible that sex or age class has little or no effect on group size in this area, unless one sex or class is disproportionately represented here. The apparent predominance of immature whales among stranded specimens may reflect a similar overrepresentation of juveniles in the general population; if this is the case, the abundance of singletons would agree with the finding of Kato et al. (1990b) that immature animals along with mature males tend to be solitary, whereas mature females usually form schools, especially near the pack ice.

Feeding behavior

In this study less than one percent of all minke whale sightings involved confirmed feeding behavior. The CeTAP study (1982) also reported relatively few sightings of surface feeding. The lack of surface feeding in the study area is odd given that sympatric confamilials are commonly observed feeding (e.g. humpback whales [Payne et al., 1986]; fin whales [Overholtz and Nicolas, 1979]). In other areas of the North Atlantic, minke whales are observed feeding, displaying surface lunges and rolling (Sears et al.³; Haycock and Mercer⁴). Near the San Juan Islands, off the west coast of North America, minke whales also exhibit lunging and rolling behavior during feeding (Hoelzel et al., 1989; Dorsey et al., 1990).

Off the San Juan Islands minke whales appear to prey mainly on small schooling fish (juvenile herring, *Clupea harengus*; sand lance, *Ammodytes* spp.) (Dorsey, 1983; Dorsey et al., 1990), which are also the principal food source for minke whales off the Mingan Islands (Sears et al.³). Both humpback and fin whales feed primarily on herring or sand lance in the southern Gulf of Maine (Overholtz and Nicolas, 1979; Payne et al., 1990); many observers assume that these fish also represent a principal prey of minke whales, a belief which is strengthened by the scarcity of minke whales in Massachusetts Bay during 1986 and 1987 when the local sand lance population crashed (Payne et al., 1990). However, it is not understood why these minke whales rarely exhibit feeding behavior at the surface, unless whales in this area either exploit fish schools at greater depths than do whales recorded for other feeding grounds or employ a foraging technique that does not utilize the surface for catching prey.

Nearly all minke whales observed feeding during this study were singletons, a finding which is simi-

lar to that reported from other areas such as the western coast of North America where minke whales appear to act independently of each other even though several individuals may be present in the same area while feeding (Hoelzel et al., 1989; Dorsey et al., 1990). According to many studies (Ivashin and Votrogov, 1981; Bushuev, 1991, Sears et al.³), minke whales tend to group together when food is abundant, but it was unclear whether these animals were feeding cooperatively or were drawn to the same area by the availability of food and were feeding independently.

Conclusion

In general, both the yearly and seasonal distribution of minke whales in Massachusetts Bay and Cape Cod Bay is similar to that found for other populations of this species. The data in this study also generally agree with other published information pertaining to group size, feeding behavior, and the occurrence of mother-and-calf pairs. Unfortunately, because the social structure and group composition of the minke whales observed in this study are unknown, it is impossible to determine whether or not the minke whales of Massachusetts and Cape Cod bays exhibit the same segregational patterns that have been suggested for other populations of this species in both the northern and southern hemispheres. It would also be valuable to explore whether individual minke whales return to the same area from year to year as documented off the west coast of North America, or whether the minke whales seen here represent transient individuals from one or more populations. Continued study with an emphasis on photographic identification of individuals is greatly needed as well as continued work in the biopsy of individuals throughout the year in order to gain some insight on the sex ratio, genetic structure, and group composition of this and other populations.

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⁴ Haycock, C. R., and S. N. Mercer. 1984. Observations and notes on the abundance and distribution of cetaceans in the Eastern Bay of Fundy near Brier Island, Nova Scotia, in August and September 1984. Unpubl. Rep.

minke whales really are whales and for allowing me extra time to see whether they really do anything besides breathe. This study was made possible in part by funding for data management provided by the U.S. National Marine Fisheries Service (Northeast Fisheries Center) under contract 50-EANF-9-00033.

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